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COMPARING PERFORMANCE OF TWO METHODS TO PROCESS INERTIAL DATA IN GAIT ANALYSIS

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INTRODUCTION

Optical motion capture (OMC) systems are extensively used and validated to acquire and analyze both healthy and pathological gait patterns, however they are limited to laboratory environments and do not allow for analysis in the subjects' daily living environment. Inertial motion capture (IMC) systems are an alternative to OMC systems without the restriction of a laboratory environment. However, the accuracy of the estimated subject kinematics using IMC is typically degraded by magnetic distortions present in the environment. Recently, new methods for IMC systems have been developed that do not suffer from this drawback and reliably estimate subject kinematics irrespective of the magnetic environment. The purpose of this study was to compare the performance of two IMC based methods for gait analysis against the OMC system.

METHODS

Five trials of ground level walking at self-selected speed were collected from 8 healthy young participants (2 females and 6 males; age=31.0±8.8 years; BMI=23.8±1.9kg/m^2) with no history of lower limb injuries. Kinematic data were collected using an 8-camera optical motion capture (OMC) system (Qualisys) and an inertial motion capture (IMC) system (17 sensors, MVN Link, Xsens) with both systems sampling at 240Hz. Force data from 3 force plates (AMTI) were also collected at 2400Hz and used to identify complete gait cycles of each leg.

Hip, knee and ankle angles (flexion-extension [FE], adduction-abduction [AA] and internal-external [IE] rotation) from IMC were calculated using two methods; (A) the commercially available MVN Studio (Xsens) v. 4.3.1, that estimates the relative orientation between segments based on the assumption that a homogeneous magnetic-field is measured by all 17 sensors [1] and (B) estimation of the relative orientation between segments that does not rely on this assumption [2]. As a reference, joint angles were calculated from the OMC data though inverse kinematics performed in AnyBody Modeling software using a lower limb stick model [3] with the hip, knee and ankle joints modeled as spherical joints and segments' axis system matching the MVN body model.

Angles calculated using the two IMC methods were compared with the angles obtained from the OMC data in terms of Pearson's correlations coefficient (r) and root-mean-square-errors (RMSE). Differences in r and RMSE medians between methods A and B were assessed with Wilcoxon signed-rank test. Alpha was set to $p<0.05$.

RESULTS AND DISCUSSION

Both methods A and B showed good performance in reproducing the FE angles of hip, knee and ankle with high correlations obtained between IMC and OMC and RMSE lower than 7.38° in both methods (Table 1). Significantly higher correlations between OMC and IMC using method B were obtained in the hip and ankle joints for both FE and IE rotation angles compared with method A (Table 1). Method B presented significant lower RMSE relative to OMC compared with method A in adduction-abduction angle in all joints (hip, knee and ankle) and in the IE rotation for knee and ankle joints. An overall improvement in estimation of AA and IE rotations was found with method B.

Differences between systems, in particular the low correlations in IE and AA knee angles might be explained by the small values of these angles that are highly affected by soft tissue artifacts and likely not accurately measured by any of the systems. Also, the assumption of defined joint angles during the static calibration in the IMC system and differences in AnyBody and MVN model definitions are known limitations that need to be further investigated.

CONCLUSIONS

In this study we compared two different IMC based methods to extract joint angles against an optical reference. Both methods show that the joint angles can be estimated with good correlation and RMSE, especially for the flexion/extension angles. Method B outperformed method A on most variables analyzed and showed more consistent performance.

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Table 1: Data correlations coefficients (r) and root-mean-square-errors (RMSE) between OMC and IMC for method A) assumption of a homogenous magnetic field (HMF) and B) not assuming a HMF. Significant higher values (*=p<0.05).

	Correlations, r (median)						RMSE (median/degrees)					
Joint	Hip		Knee		Ankle		Hip		Knee		Ankle	
Method	A	B	A	B	A	B	A	B	A	B	A	B
Flexion-Extension	1.00	1.00*	1.00	1.00	0.96	0.98*	4.93	5.20	7.38	5.90	5.00	4.74
Adduction-Abduction	0.89	0.92	0.71	0.50	0.80	0.88	4.41*	3.28	5.94*	2.36	6.30*	4.24
Internal-External Rotation	0.46	0.59*	0.47	0.44	0.71	0.88*	7.38	5.90	11.17*	4.34	11.94*	6.22